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ROBOTICS CHALLENGE: COGNITIVE ROBOT FOR GENERAL MISSIONS

UNIVERSITY OF KANSAS

JANUARY 2015

FINAL TECHNICAL REPORT

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14. ABSTRACT

To operate properly in a complicated environment, a robotic system requires both high-level command facilities and low-level sensing/control mechanisms. This report describes a powerful combination of a cognitive architecture at the high-level and the whole-body motion control at the low-level. The team has achieved significant technical advances in relation to its robot control architecture, a remote operator station, and an integrated system with proper movement controls.

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1.0 Summary

This grant supported research and development necessary to prepare the University of Kansas (KU) and the Korea Institute of Science and Technology (KIST) team for competing at the DARPA Robotics Challenge. As a participant in Track B, the team was required to enter a Virtual Robotics Challenge at the end of Phase 1 of this project. The KU–KIST team was unsuccessful at this event and did not continue to the next phase. However, the software each team member has developed provides an excellent infrastructure for future research in robotics and related fields, as detailed in this document.

2.0 Introduction

This final report summarizes outcomes from the project titled, Robotics Challenge: Cognitive Robot for General Missions,[1] granted to the University of Kansas (KU) and the Korea Institute of Science and Technology (KIST). This report is intended to provide any interested researchers in related fields, as well as the funding agency, necessary information to measure the outcomes of the project and make informed decisions based on its findings both positive and negative.

This project aimed to provide an architecture for commanding and controlling a government-furnished equipment (GFE) in the form of a humanoid robot from Boston Dynamics and its simulation. As a participating team in Track B of the DARPA Robotics Challenge, the collaboration between the University of Kansas (KU) and the Korea Institute of Science and Technology (KIST) was intended to combine two very distinct expertise from these organizations. Namely, the project was designed to leverage on KIST¹s experience in designing and developing control software for humanoid robots at lower levels and KU¹s expertise in cognitively inspired architectures for higher-level, symbolic control.

More specifically, researchers from KIST has extended their own robot control architecture called IHC to work with the simulated GFE robot, while the KU researchers has worked on extending a cognitive architecture called ICARUS for higher-level mission control and developing interfaces between a variety of components in the intended overall system.

3.0 Methods, Assumptions and Procedures

The basic strategy our team has taken can be summarized as a collaboration between KU and KIST as two organizations with distinct expertise. The split of the technical work was very clear, in that KU took responsibility for higher-level mission command and operator interfaces while KIST was in charge of lower-level control of the robot.

To achieve the intended goal of this project, namely, developing a control system for the GFE robot in the competition setting, our team has proposed to take and extend existing software at KU and KIST. Dr. Choi at KU has extended the ICARUS cognitive architecture he has co-developed with his former colleagues for the purpose of this competition. Dr. Kim at KIST started with the existing version of IHC, originally developed to control KIST¹s own Mahru humanoid robots, and adapted it for Boston Dynamics¹ ATLAS robot. The operator interface software was, however, developed from scratch by a group of students at KU under the supervision of Dr. Choi.

As a basis for these extension works, the team has made a series of technical assumptions. The KIST researchers assumed that 1) they would have a complete access to ATLAS and its simulation; 2) the interface with the simulator is flawless; and 3) the IHC software is essentially bug-free and readily adaptable for the new robot. In the mean time, people at KU assumed that 1) the IHC¹s low-level control is perfect ‹ meaning that the robot can perform basic maneuvers like walking without interventions from the ICARUS architecture and 2) the competition rules require continuous execution of tasks in a single operation making it necessary to have a powerful goal switching mechanism at the high level of the system.

Based on these assumptions, the execution is procedurally straightforward involving the KU-developed operator station, the ICARUS architecture with a competition-specific knowledge base, and KIST¹s IHC all communicating over a TCP network. Then the system would connect to the simulated environment over the competition's network infrastructure.

4.0 Results and Discussion

Over the duration of this project, the team has made significant technical progress. Despite the early termination of the project due to the VRC result, both research groups at KU and KIST have achieved the following:

4.1 Major rewrites of IHC (Humanoid Control Architecture)

As a subcontractor in the team, KIST entered the Robotics Challenge with their existing robot control architecture, IHC. In the past, the system had proved to be an excellent software for a humanoid robot, Mahru, which was built in-house at KIST. However, the architecture was not previously used on a different robot platform and had lacked the compatibility and stability necessary to serve as an off-the-shelf control system for ATLAS platform and its simulation on Gazebo. Dr. Doik Kim and his student focused on enhancing the compatibility of IHC and adapting the architecture for the purpose of the Robotics Challenge. This process involved rewriting and debugging major portions of the code.

4.2 Operator Station for Remote Autonomous Control

Dr. Choi and his students at KU developed the software for an operator station that was designed to be a remote command and control facility for the ATLAS platform (see Figure 1). The operator station acts as a middleware that connects Dr. Choi's ICARUS cognitive architecture that receives sensor data and transmits command signals with the robot platform at a remote location. The communication module in this software was designed to minimize internet traffic by acting as a maintainer of the sensory data that are requested and updated only when specifically requested by ICARUS. In the event of communication delay or failure, ICARUS was able to use slightly-dated, but often still-usable sensory data. The operator station was developed in a generic and modularized fashion to allow its future usage with virtually any robotic platform.

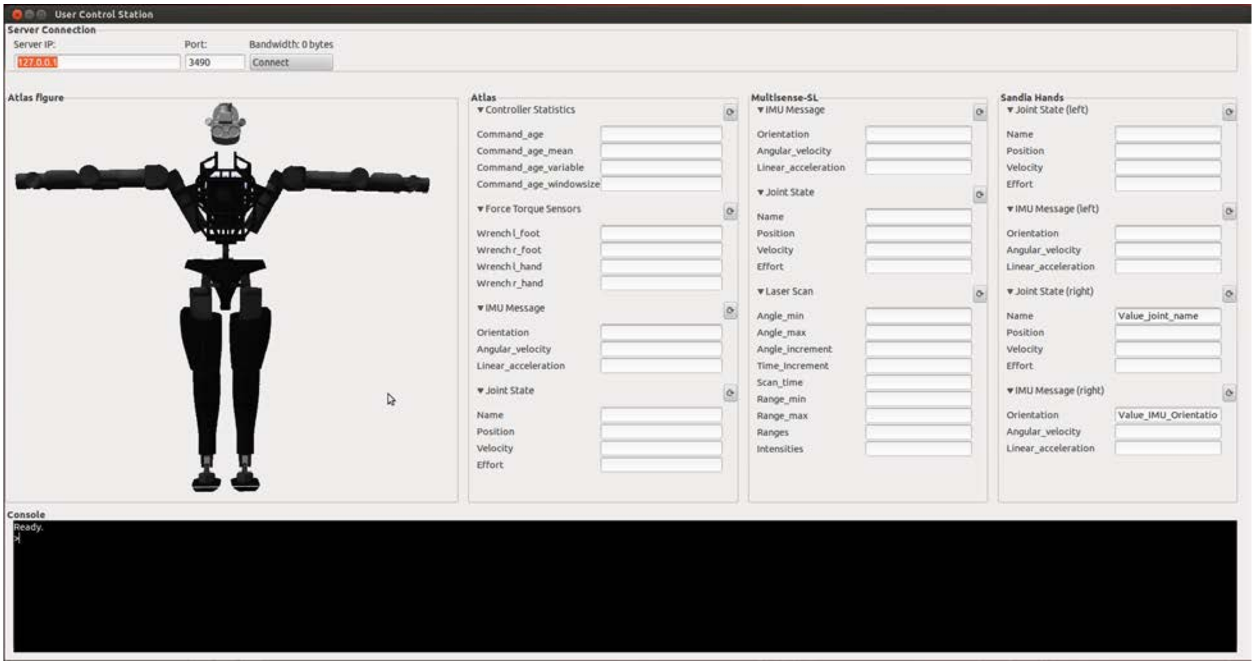

Figure 1: A Screenshot of the Operator Station

4.3 IHC and Operator Station Integration

The KIST and KU researchers jointly worked on the integration of IHC and the operator station. Since IHC is written as C++ libraries, the process of integrating the two software was relatively straightforward. The operator station is registered as a module in IHC framework that acts as a wrapper software around ICARUS's decision making procedures.

4.4 Stable Walking in VRC Environments

The team had initially experienced difficulty in making the ATLAS robot to walk stably over nontrivial surfaces. Through the continued efforts on the KIST side even after the VRC event, IHC successfully controlled the robot to walk on a variety of surfaces. Figure 2 shows a simulated ATLAS robot with IHC's control performing some of these walking motions.

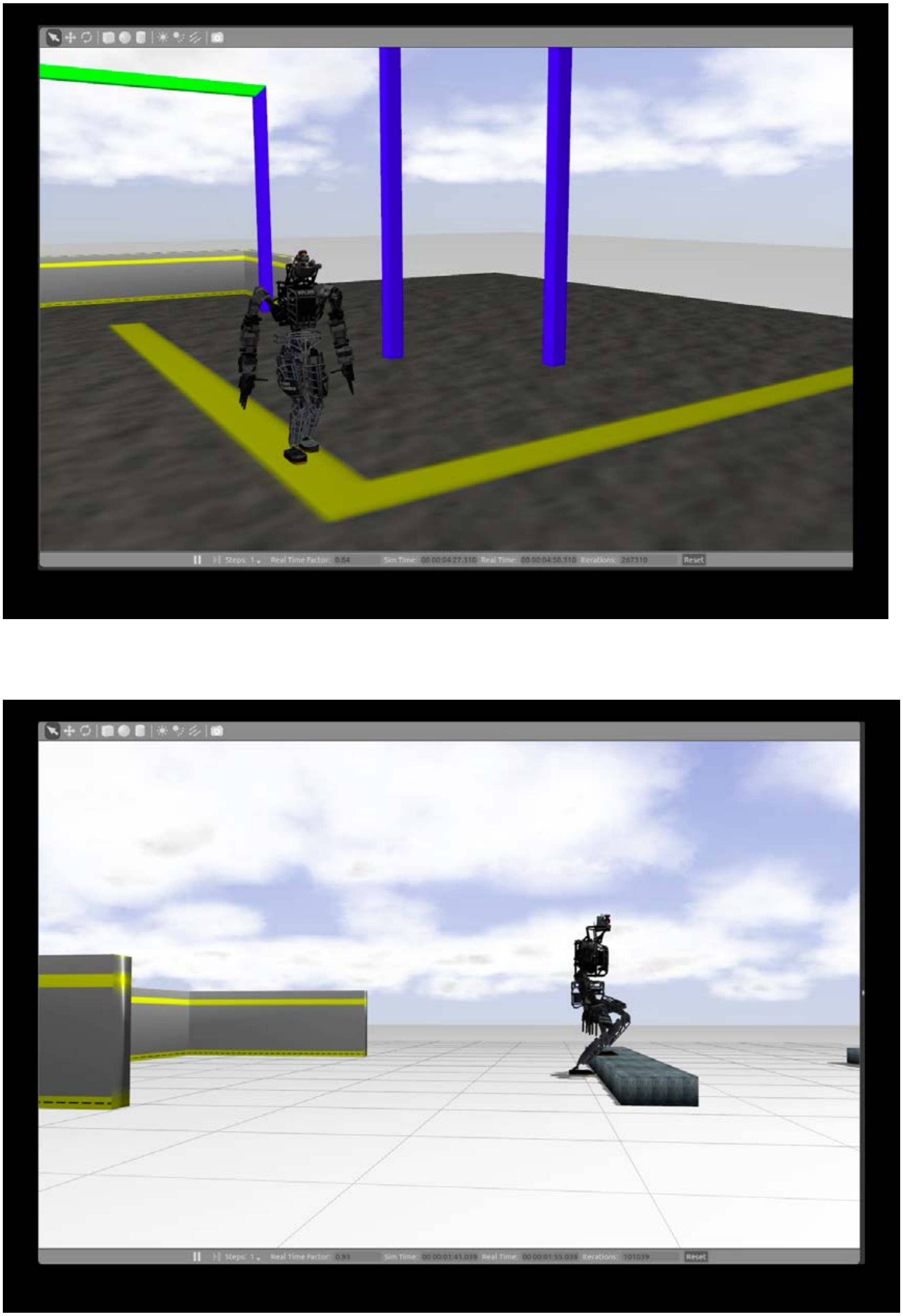

Figure 2: Screenshots of the IHC-Controlled ATLAS Robot Walking

4.5 Discussion

Despite the technical achievements outlined above, our team lacked the timely administrative support from the subcontractor organization. The subcontracting process was delayed significantly for roughly six months. The PI had assumed that at least some technical work would be done by the subcontractor during this period although the final subcontract was yet to be signed. However, this did not happen in reality and it caused a serious shortage of time toward the end of Phase 1. This was one of the main factors that resulted in the team's undesirable outcome at the VRC event. Due to the delayed start at KIST, the subcontractor had underspent its original budget and the difference was transferred back to KU. With DARPA approval, Dr. Choi used this fund to facilitate future research in the related direction as showcased in the Robotics Challenge.

5.0 Conclusions

In summary, the KU–KIST team had achieved significant technical advances in relation to its robot control architecture, a remote operator station, and an integrated system with proper movement controls for the ATLAS robot. Although the administrative challenges the team had encountered resulted in the eventual lost at the VRC event, the team attempted to maximize the impact of the resources granted by DARPA for current and future research in robotics. The team is grateful to DARPA for the opportunity to participate in the exciting event and the financial support granted to the team.